NOAA Technical Memorandum NMFS-PIFSC-27

September 2011

Status Review Report of 82 Species of Corals Under the U.S. Endangered Species Act

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National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Highlights

- Biological Review Team (BRT) established Feb.-Apr. 2010.
  - 7 members, 2 external to NOAA (USGS & NPS)
- Draft Status Review Report reviewed by Center for Independent Experts (and NMFS mgmt/GC) in Nov. 2010
  - Draft revised taking into consideration reviewer comments
  - NOAA Technical Memorandum NMFS-PIFSC-27 published Sep. '11
- Status Review Report includes:
  - Synopses for each of the 82+ candidate coral species
  - Information on potential threats to their existence
  - Estimates of their risk of extinction by 2100
- Ocean warming, disease, and ocean acidification, all directly or indirectly related to greenhouse gas emissions, were considered to pose greatest extinction risk to 82 candidate corals

Status Review Process & Timeline

Oct. 20, 2009	Center for Biological Diversity Petitioned NMFS to list 83 species of coral under ESA
Feb. 10, 2010	NMFS 90-day finding - 82 candidate coral species
Jan-May 2010	Literature Reviews/Data Compilation/Coordination Meetings
May. 9, 2010	PIFSC & SEFSC Directors established a 7 member Biological Review Team (BRT) with scientists from 5 NOAA Offices, 1 NPS, 1 USGS; Terms of Reference to assess status of and provide estimates of the risks of extinction for the 82 candidate coral species
May-Dec. 2010	Weekly BRT Conference Go-To-Meeting Calls
May. 10-13, 2010	1st BRT Workshop, Honolulu, HI
Jul. 14-18, 2010	2nd BRT Workshop, Seattle, WA
Sep. 20-24, 2010	3rd BRT Workshop, Honolulu, HI
Oct. 28, 2010	Submitted Draft Status Review Report for CIE Review
Nov. 26, 2010	CIE Reviews Completed and Provided to BRT (also received reviews from NMFS Management and General Counsel
Dec.'10-Aug. 2011	BRT addressed Reviewer Comments and Finalized Status Review Report
Sep. 2011	Published Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act: 530 pp., ~2150 citations.
Apr. 13, 2012	Status Review Report posted publicly
Jun. 18, 2012	82 Corals Science Workshop: Pacific
Jun. 27, 2012	82 Corals Science Workshop: Atlantic

Biological Review Team

Member	Affiliation	Expertise
Dr. Rusty Brainard, chair	NOAA-PIFSC	Coral reef ecosystem monitoring in Pacific, oceanography, ocean acidification
Dr. Margaret Miller	NOAA-SEFSC	Coral biology/ecology, focus on W. Atlantic/Caribbean
Dr. Paul McElhany	NOAA-NWFSC	Population viability analysis, risk assessment models, ocean acidification
Dr. Mark Eakin	NOAA-NESDIS CRW	Coral ecology, coral bleaching, satellite remote sensing, climate prediction
Dr. Greg Piniak	NOAA-NCCOS	Coral reef ecology, nearshore processes, land-based sources of pollution
Dr. Chuck BIrkeland	USGS-HCFU	Coral reef biology/ecology in Pacific
Matt Patterson	NPS-IMFCN	Coral reef monitoring in W Atlantic/Caribbean

Internal Workshops with Subject Matter Experts

- Marlin Atkinson, Univ of Hawai`i (UH) Hawai`i Institute of Marine Biology (HIMB), Kāneohe Hawai`i
- Eric Brown, National Park Service, Molokai, Hawai`i
- Steve Coles, Hawai`i Biological Survey, Honolulu, Hawai`I
- RIchard Feely, NOAA Pacific Marine Environmental Laboratory, Seattle, Washington
- Douglas Fenner, Dept. Marine & Wildlife Resources, American Samoa
- Mike Field, U.S. Geological Survey, Santa Cruz, California
- Zac Forsman, UH HIMB, Kāne`ohe, Hawai`i
- Ronald Hoeke, UH Joint Institute for Marine and Atmospheric Research [JIMAR]-NOAA Coral Reef Ecosystem Division (CRED), Honolulu, Hawai`I and CSIRO, Melbourne, Australia
- Paul Jokiel, UH HIMB, Kāneohe, Hawai`i
- Jean Kenyon, UH JIMAR-CRED and U.S. Fish & Wildlife Service (USFWS), Honolulu, Hawai`i
- Chris Langdon, University of Miami, Miami, Florida
- Lynn Maguire, Duke University, Durham, North Carolina
- Jim Maragos, USFWS, Honolulu, Hawai`i
- Richard H. Randall, University of Guam, Mangilao, Guam
- Bernardo Vargas-Ángel, UH JIMAR-CRED, Honolulu, Hawai`i

Subject Matter Experts & Data

- Charlie Veron, Australian Institute of Marine Science
- David Burdick, Government of Guam
- Ester Peters, George Mason University
- Thad Murdock, Bermuda Zoological Society
- Samantha dePurtron, Bermuda Institute of Ocean Sciences
- Chris Caldow & Sarah Hile, NOAA National Ocean Service, Biogeography Branch
- Marcia Creary, CARICOMP
- Daniel Mauricio Rozo Garzon, Sven Zea, Raul Navas, Instituto de Investigaciones Marinas y Costeras
- Judy Lang and Ken Marks, Atlantic Gulf Rapid Reef Assessment
- Beth Polidoro, IUCN Species Programme
- Elizabeth White, CITES Species database
- UNEP World Conservation Monitoring Centre
- Mark Chiappone, Univ of North Carolina-Wilmington
- Rob Ruzicka, Florida Marine Research Institute
- Dwight Gledhill, NOAA Atlantic Oceanographic and Meteorological Laboratory
- Andrew Baird, Australian Research Council Ctr of Excellence for Coral Reef Studies, James Cook Univ
- Joshua Voss, Harbor Branch Oceanographic Institute
- William Fischer, US Environmental Protection Agency
- William 'Jeff' Miller and Andrea Atkinson, National Park Service
- Todd LaJeunnese, Penn State Univ
- Jennifer Smith, Scripps Institution of Oceanography

Status Review Report: Contents

- Chapter 1 – Introduction
  - Scope and Intent of Status Review
  - The Petition
- Chapter 2 – Background on Corals and Coral Reefs
  - Taxonomy and Distribution
  - Biology
  - Ecology of Coral Reef Ecosystems
  - Status/Ecological History of Caribbean Reefs
  - Contrasts: Caribbean & Indo-Pacific Reefs
  - Status/Ecological History of E. Pacific Reefs
- Chapter 3 – Threats to Coral Species
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  - Global Climate Change & Large-Scale Threats
  - Local Threats
  - Interactive and Cryptic Threats
- Chapter 4 - Demographic and Spatial Factors in Evaluation of Risk
  - Abundance/Productivity of Corals
  - Spatial Structure of Corals
  - Diversity of Corals
  - Critical Risk Threshold
  - CRT & Depensatory Processes
  - CRT & Sexual Reproduction
- Chapter 5 – Methods
  - The Species Question
  - Data Review
  - Risk Hypotheses
  - Evaluation of Risk Hypothesis
  - BRT Voting
  - Strengths and Limitations
- Chapter 6 – Individual Species Accounts for All 82 Species
- Chapter 7 – Synthesis of Risk Assessments

The Species Question

- Is each candidate coral is a "species" under the ESA (a group of organisms that 'interbreed when mature' and are reproductively isolated from other such groups [common gene pool is separate and distinct from others]?

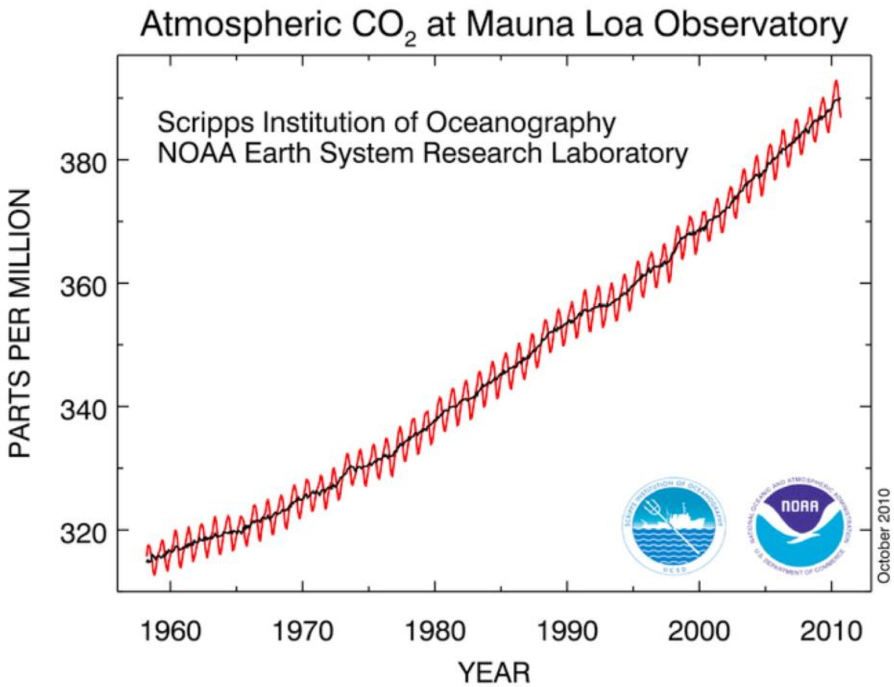
  - Most corals 'species' have been described by classical taxonomy relying on similarities and differences in morphology.   Corals are especially plastic in their morphology depending on the environmental conditions under which they live.
  - The degree of environmental versus genetic determination of morphological characteristics determines the degree to which morphologically-classified species designations accurately reflect 'true' biological species (i.e. interbreeding and reproductively isolated groups).
  - Genetic studies have shown that morphological taxonomies poorly reflect the genetic species status within many coral genera.
  - Evolutionary history of corals is marked by reticulate processes – individual lineages have repeated cycles of divergence and convergence.

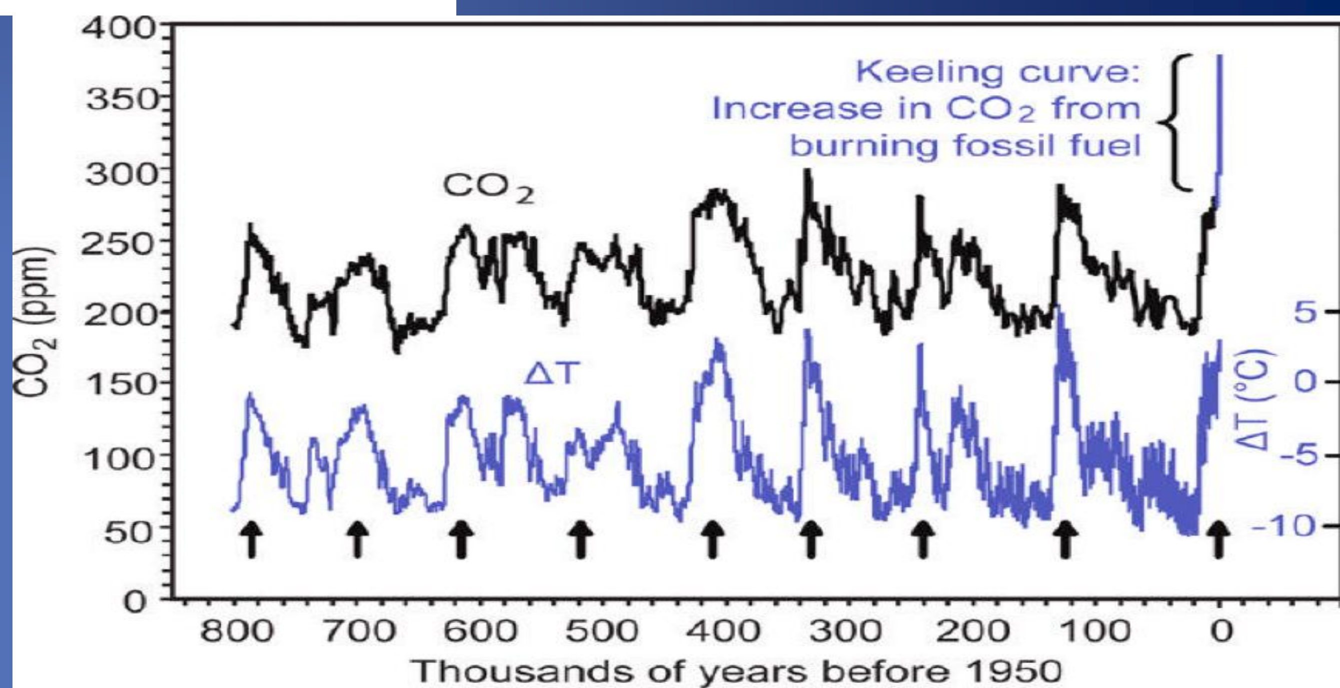
  - The BRT used solid genetics information when it existed, but defaulted to morphological descriptions when genetic studies were not available (e.g. for most of the 82 candidate species).

Evaluation of Extinction Threats

Scale	Proximate Threat	Importance
Global	Ocean Warming	High
Local	Disease	High
Global	Ocean Acidification	Med-High
Local	Reef Fishing—Trophic Effects	Medium
Local	Sedimentation	Low-Medium
Local	Nutrients	Low-Medium
Global	Sea-Level Rise	Low-Medium
Local	Toxins	Low
Global	Changing Ocean Circulation	Low
Global	Changing Storm Tracks/Intensities	Low
Local	Predation	Low
Local	Reef Fishing—Habitat Impacts /Destructive Fishing Practices	Low
Local	Ornamental Trade	Low
Local	Natural Physical Damage	Low
Local	Human-induced Physical Damage	Negligible-Low
Local	Aquatic Invasive Species	Negligible-Low
Local	Salinity	Negligible
Local	African/Asian Dust	Negligible
Global	Changes in Insolation	Probably Negligible

Carbon dioxide is rising and is now at highest levels in over 800,000 and probably 24 million years





Anthropogenic carbon dioxide emissions are accelerating and near or exceeding worst-case scenarios used in IPCC 4th Assessment Report (2007)

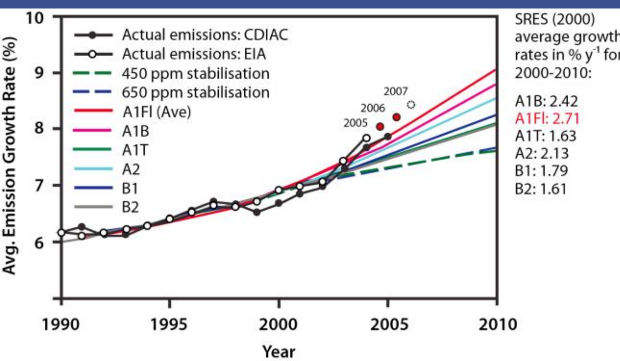
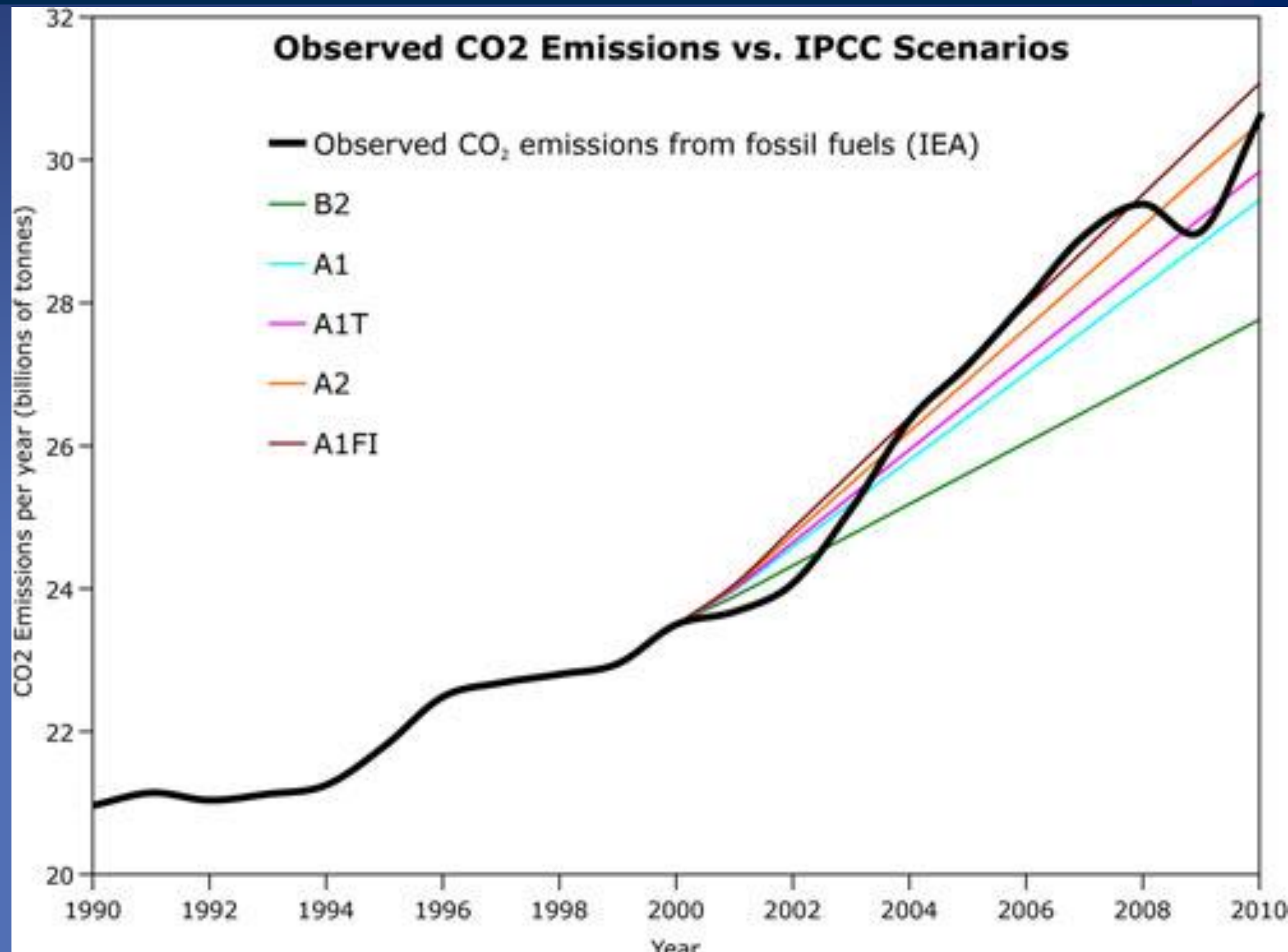
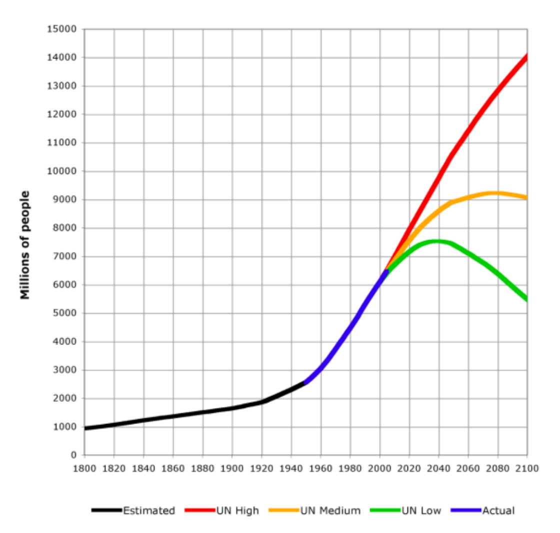


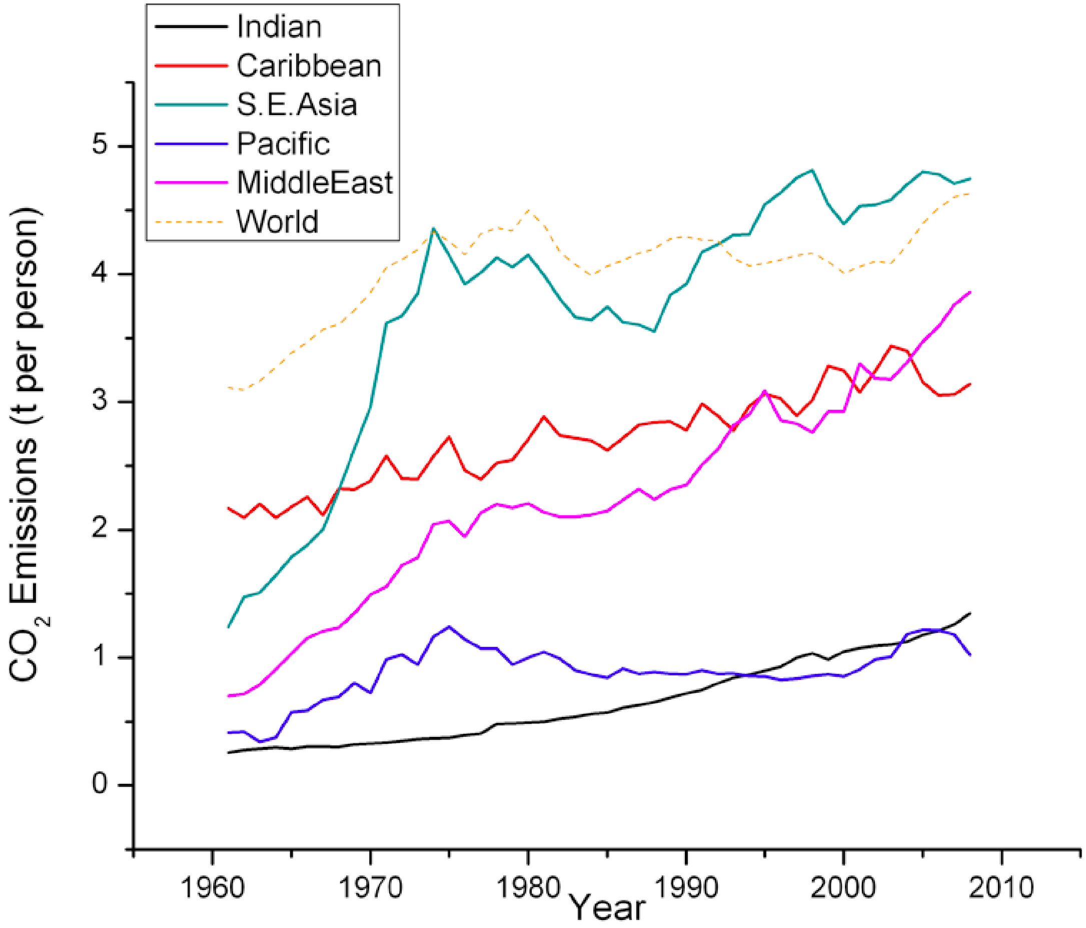
Figure 3.2.3 from Brainard et al. 2011



From www.carbonbrief.org, data from US Energy Info. Agency

Per capita emissions rising rapidly as well

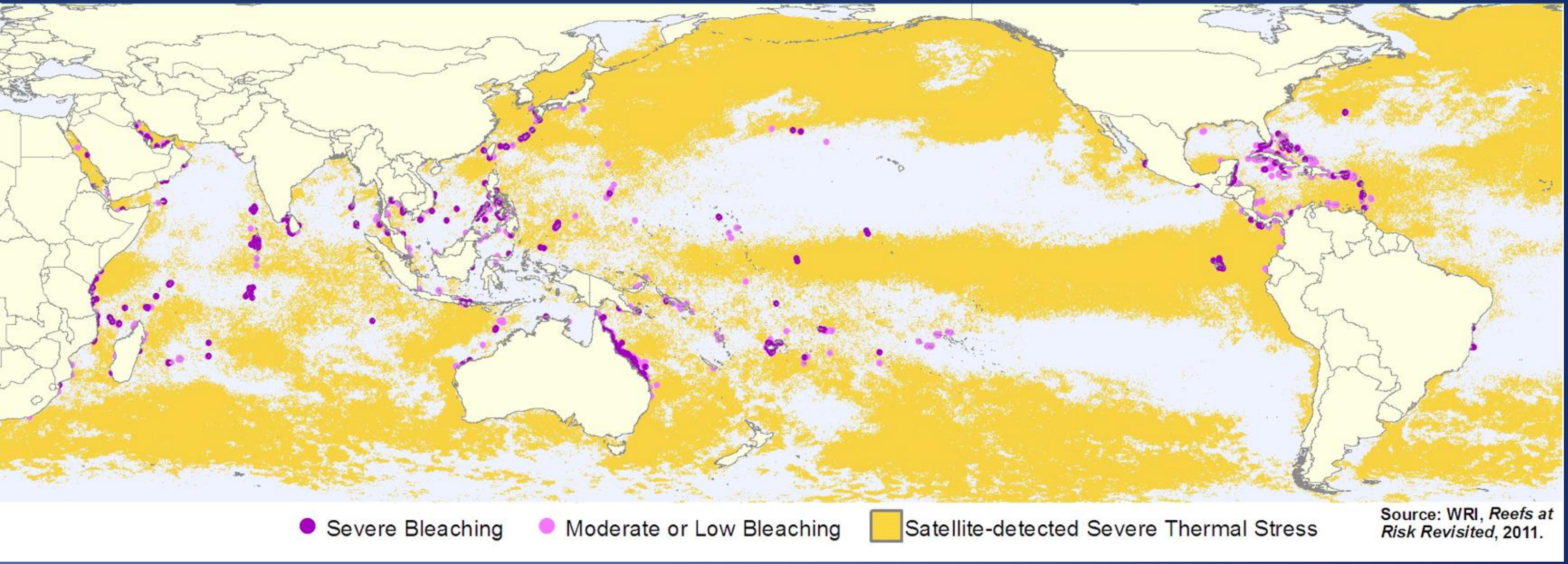


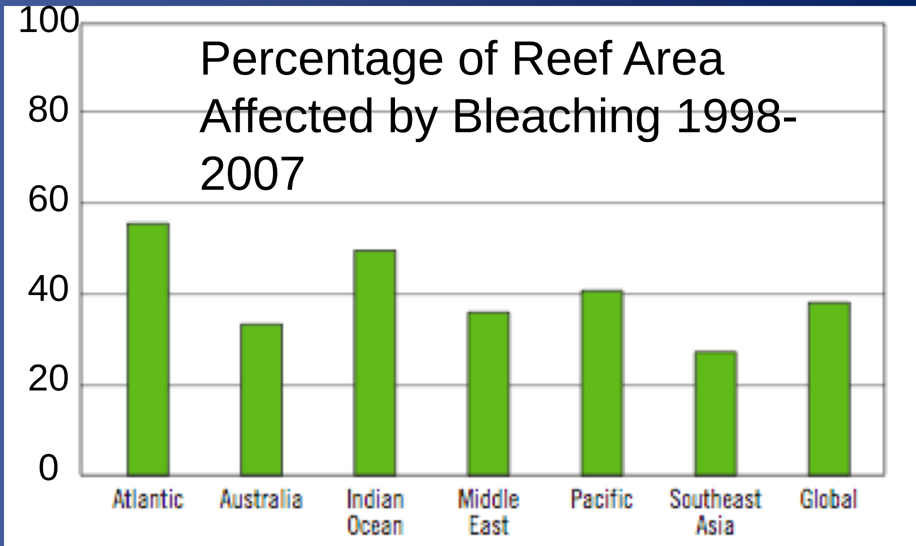


Ocean Warming

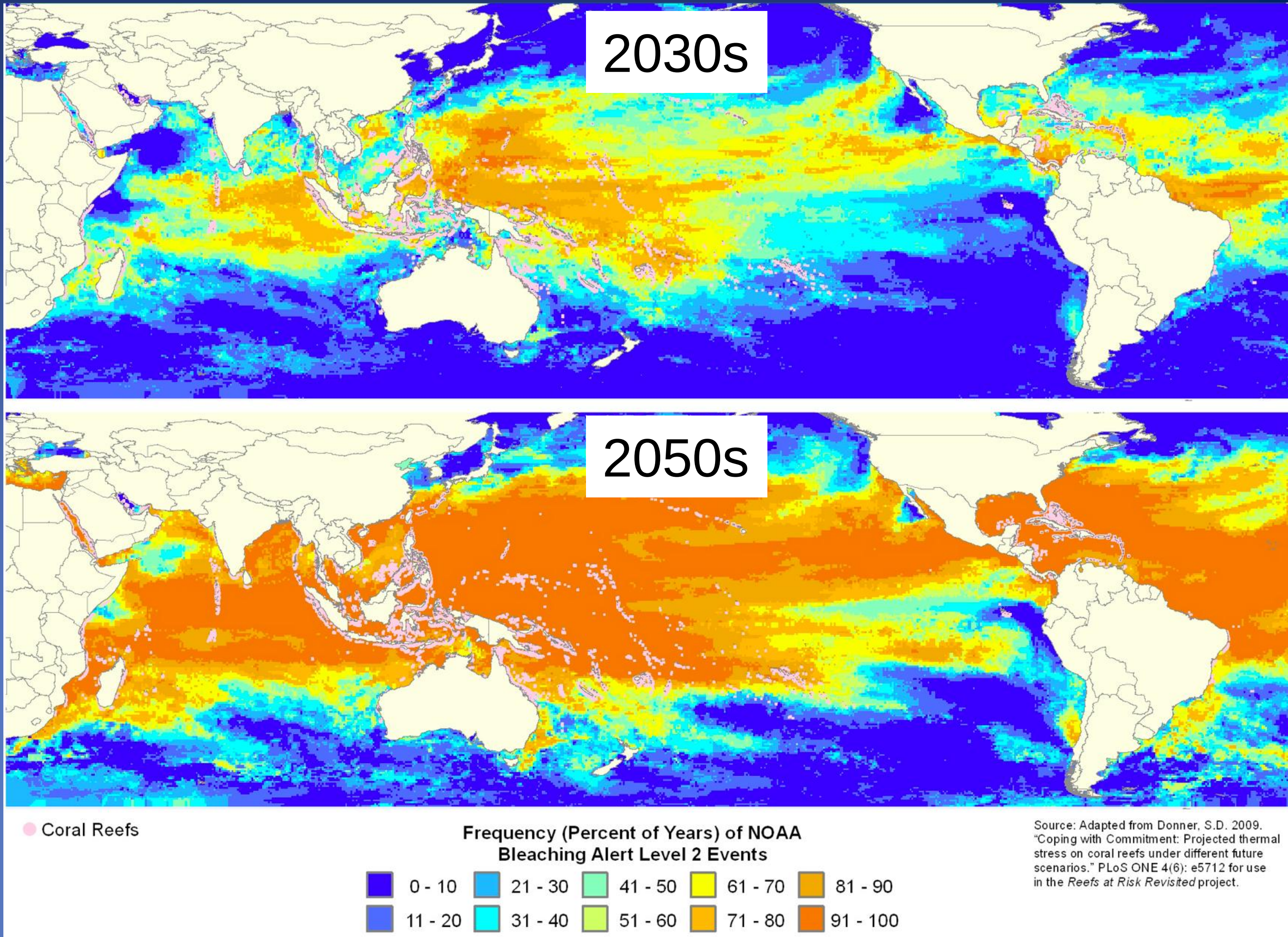
- Warming of coral reef waters has been accelerating,
- 2005 and 2010 were warmest years on record
- Widespread mass coral bleaching and mortality events have repeatedly occurred over past 30 yrs, increasing frequency
  - 1982/83 E. Pacific/Caribbean
  - 1997/98,Indo-Pacific
  - 2002/03 Central Pacific
  - 2005 Caribbean
  - 2010 SE Asia
- Increased prevalence of coral disease
- Impacts many life history stages
- Increased ocean stratification
  - less mixing
  - less nutrients
  - decreased productivity

Rising temperatures have already caused widespread bleaching and mortality





Ocean temperatures around reefs likely to rise 0.8°C by 2030s, 2.8°C by 2100, increasing bleaching frequency and intensity

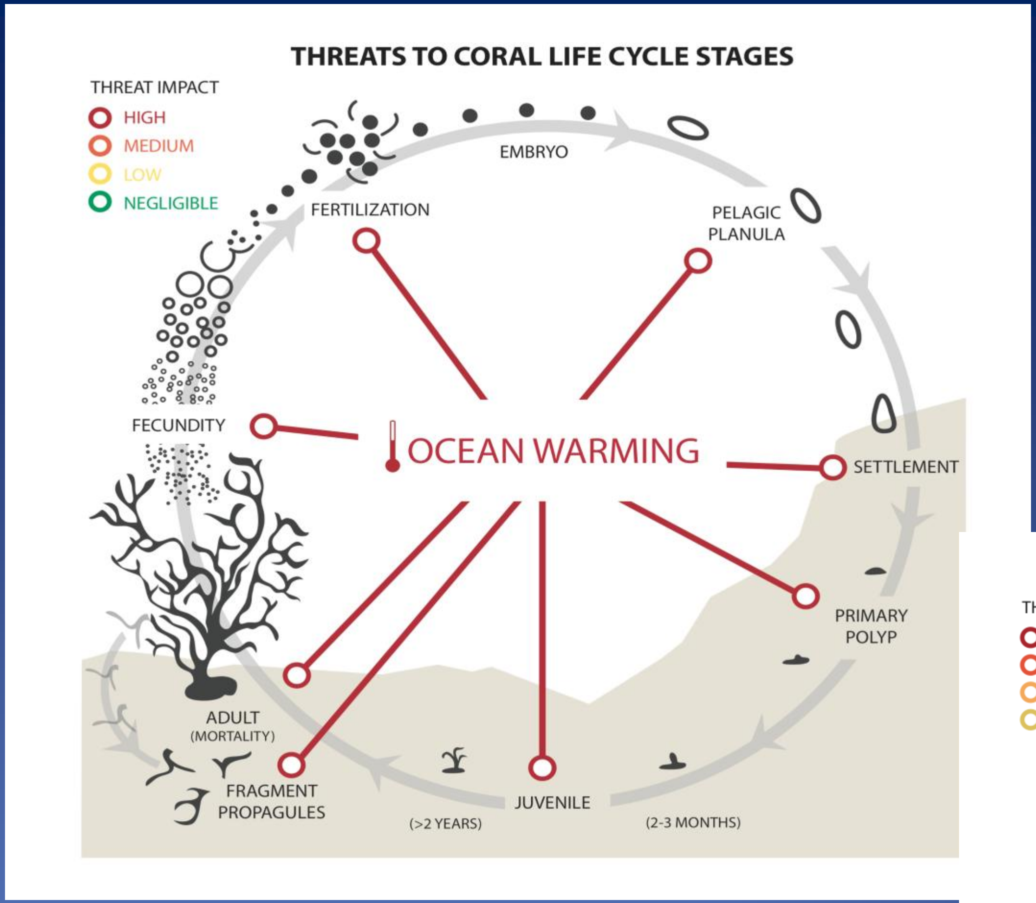


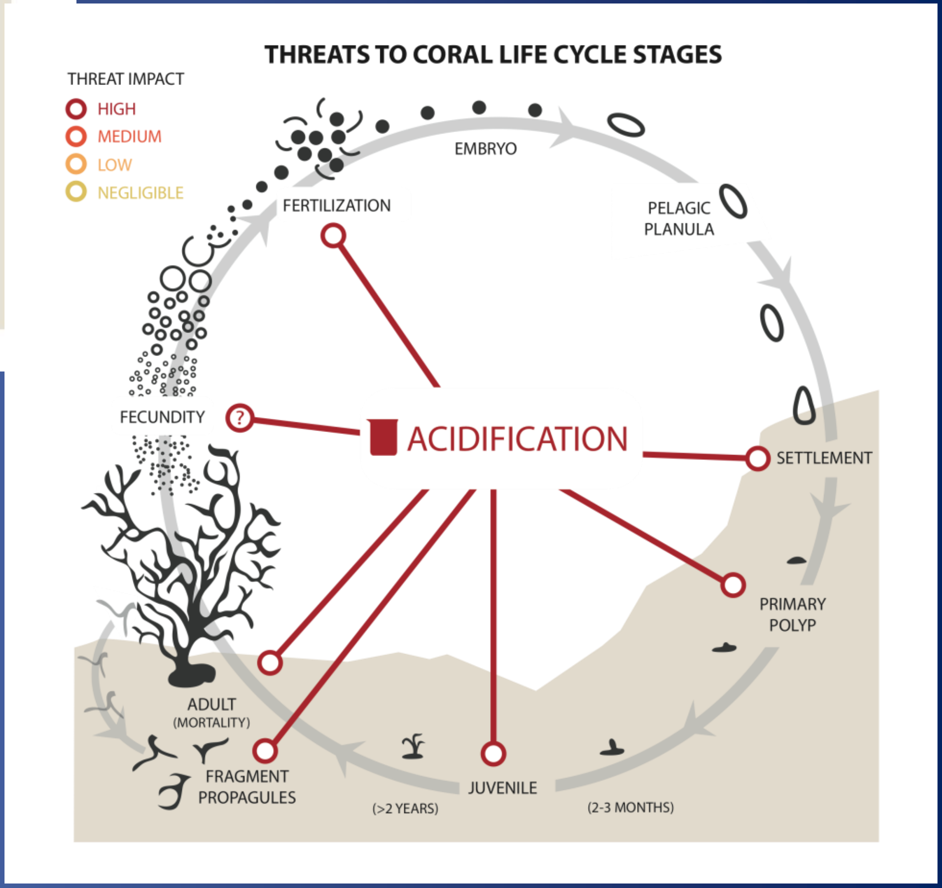
Source: Adapted from Donner, S.D. 2009. "Coping with Commitment: Projected thermal stress on coral reefs under different future scenarios." PLoS ONE 4(6): e5712 for use in the *Reefs at Risk Revisited* project.

Other Impacts of Warming

- Strong relationship between rising temperatures and increase in coral diseases
- Evidence high temperatures impair reproductive success
- Warming is leading to increased stratification and oligotrophy
- Potential for range shifts
  - Good news: some corals demonstrating range shifts
  - Bad News: poleward movement of corals likely limited by other factors
- Reduced reef resilience

Threats to Coral Life Cycle Stages



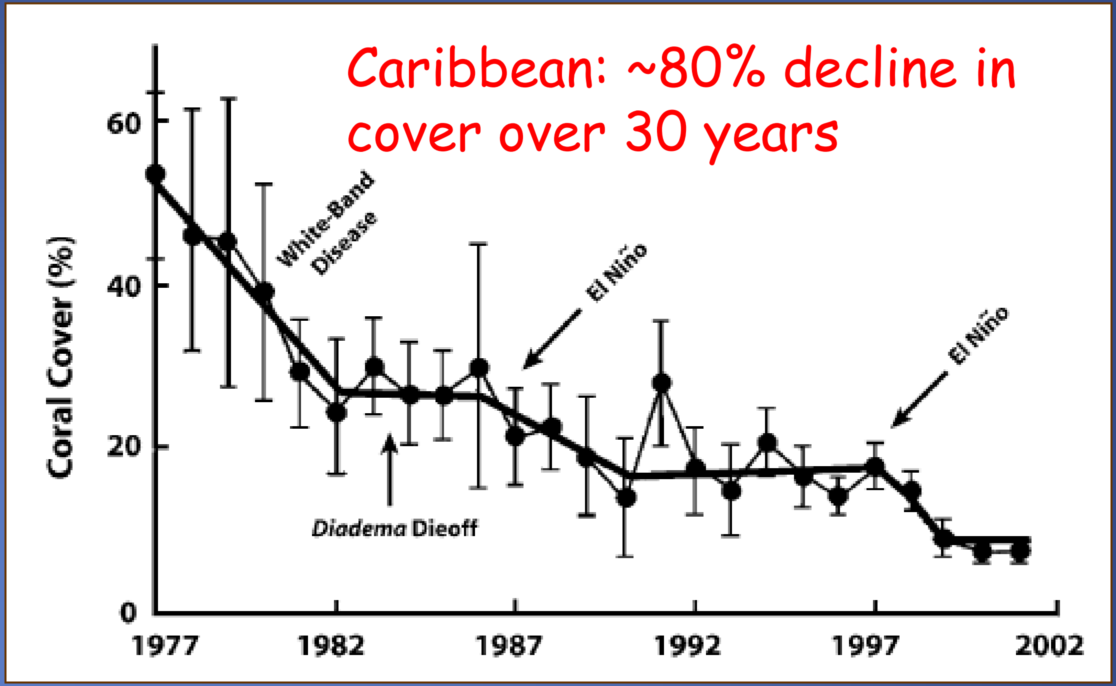


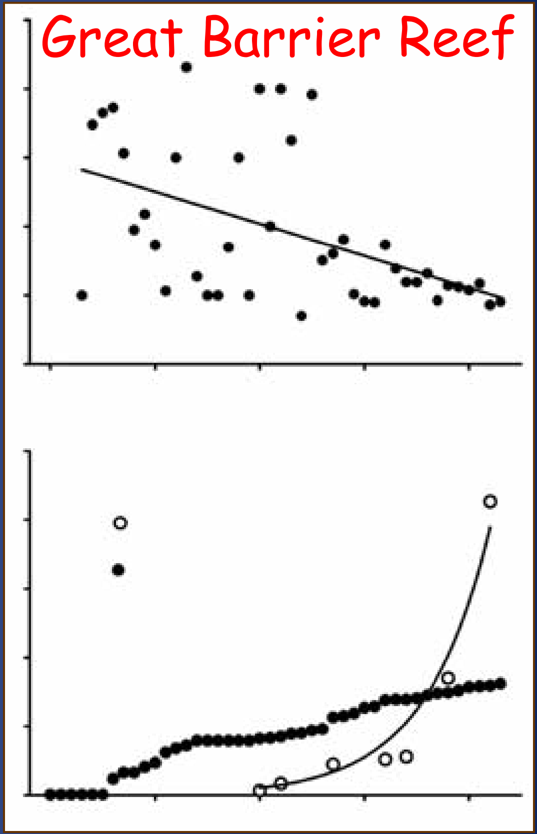
Coral Disease

- Disease – any impairment that interferes with or modifies the performance of normal functions…
- BRT focused on those diseases characterized as infectious or those attributable to poorly-described autogenous malfunctions.
- Common and devastating threat affecting most or all coral species in various life stages in all regions.
- Emergent threat – not recognized prior to devastating effects on Caribbean Acropora species beginning in the early 1980s.

Coral Reef Declines

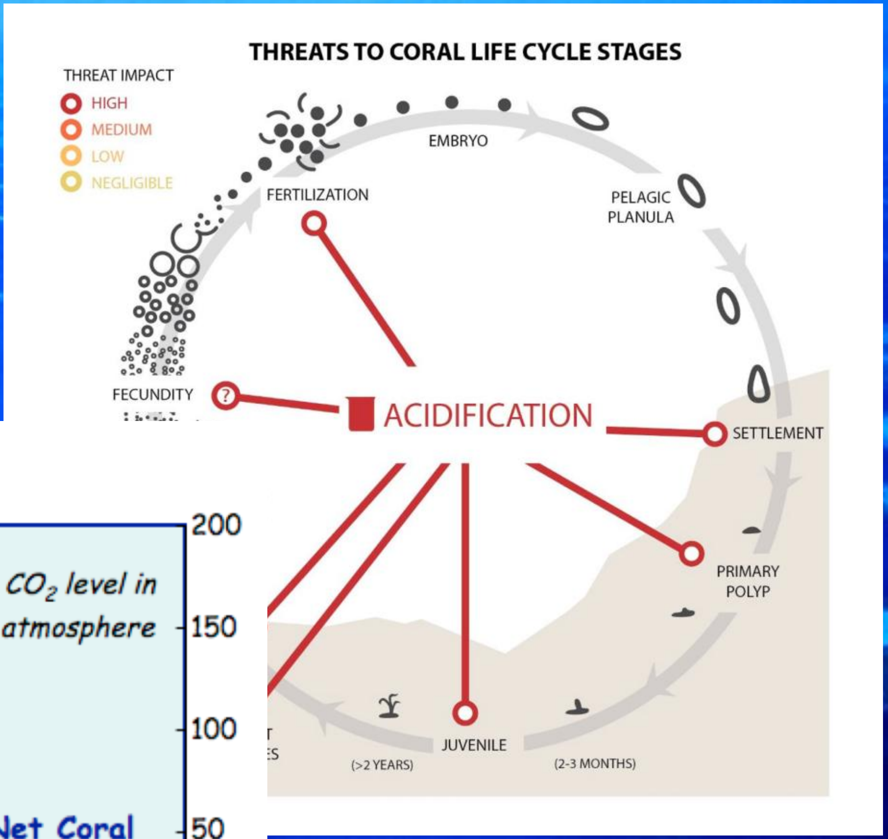
Broad scientific consensus that coral reef ecosystems are being rapidly degraded world-wide (Bellwood et al. 2004, Bruno and Selig 2007, Wilkinson 2008).

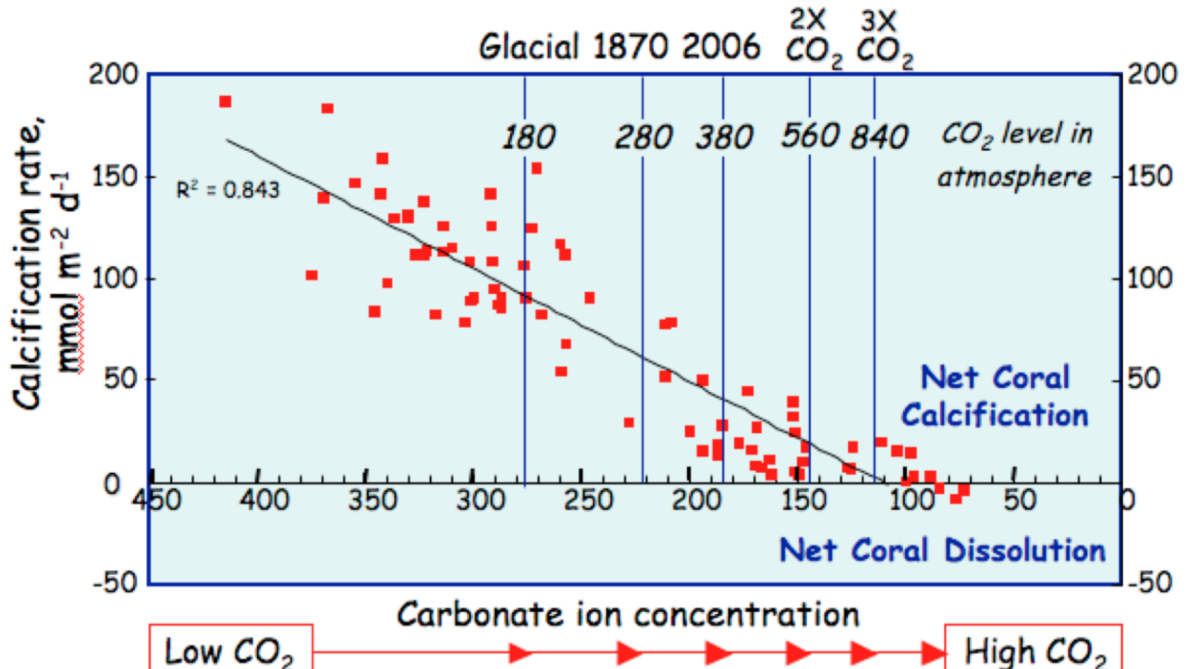




Ocean Acidification

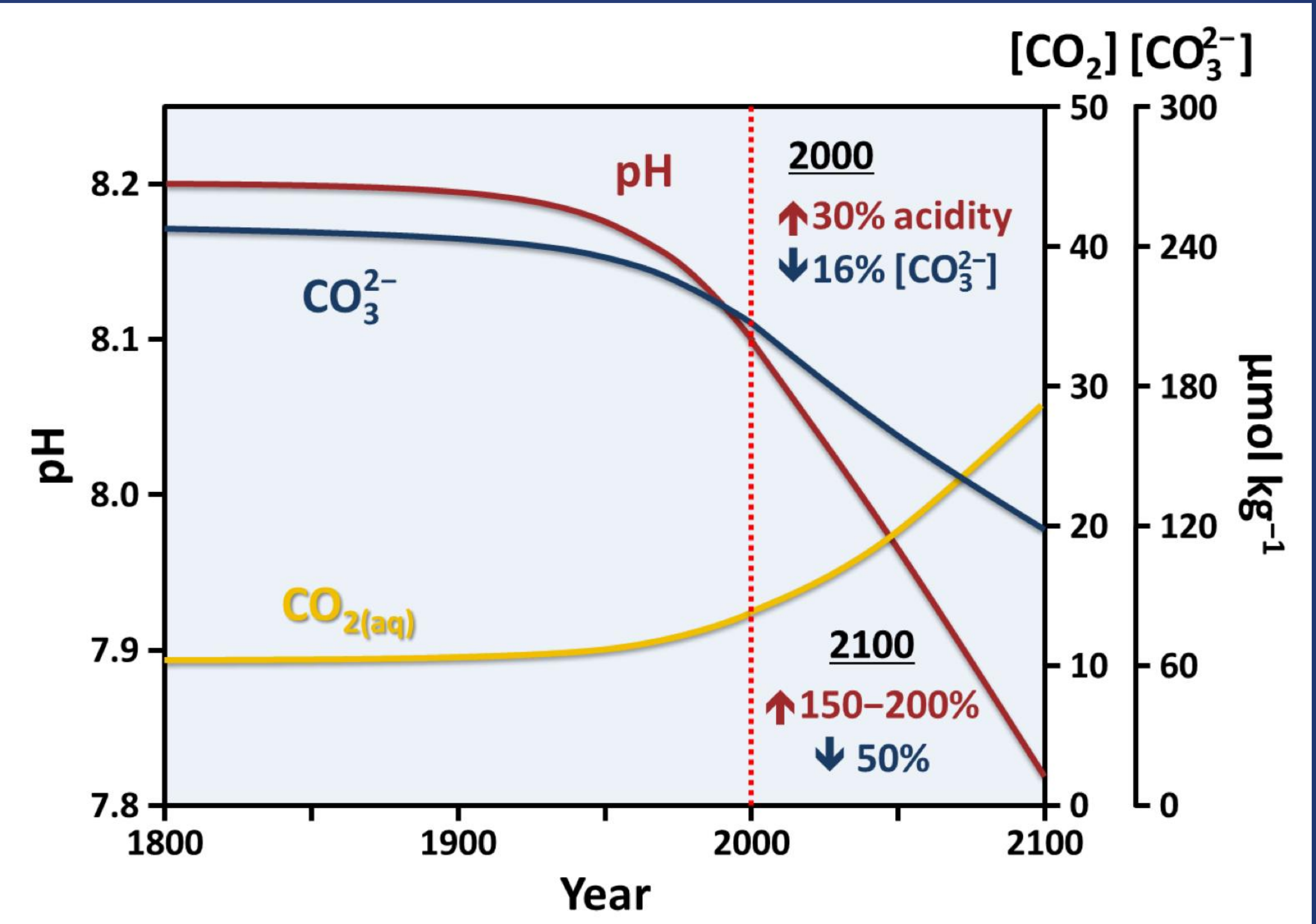
- Reduced calcification
- Increased bioerosion
- Decreased cementation
- Effects on reproduction





Langdon and Atkinson (2005)

Rising CO_2 also reducing carbonate concentrations and pH



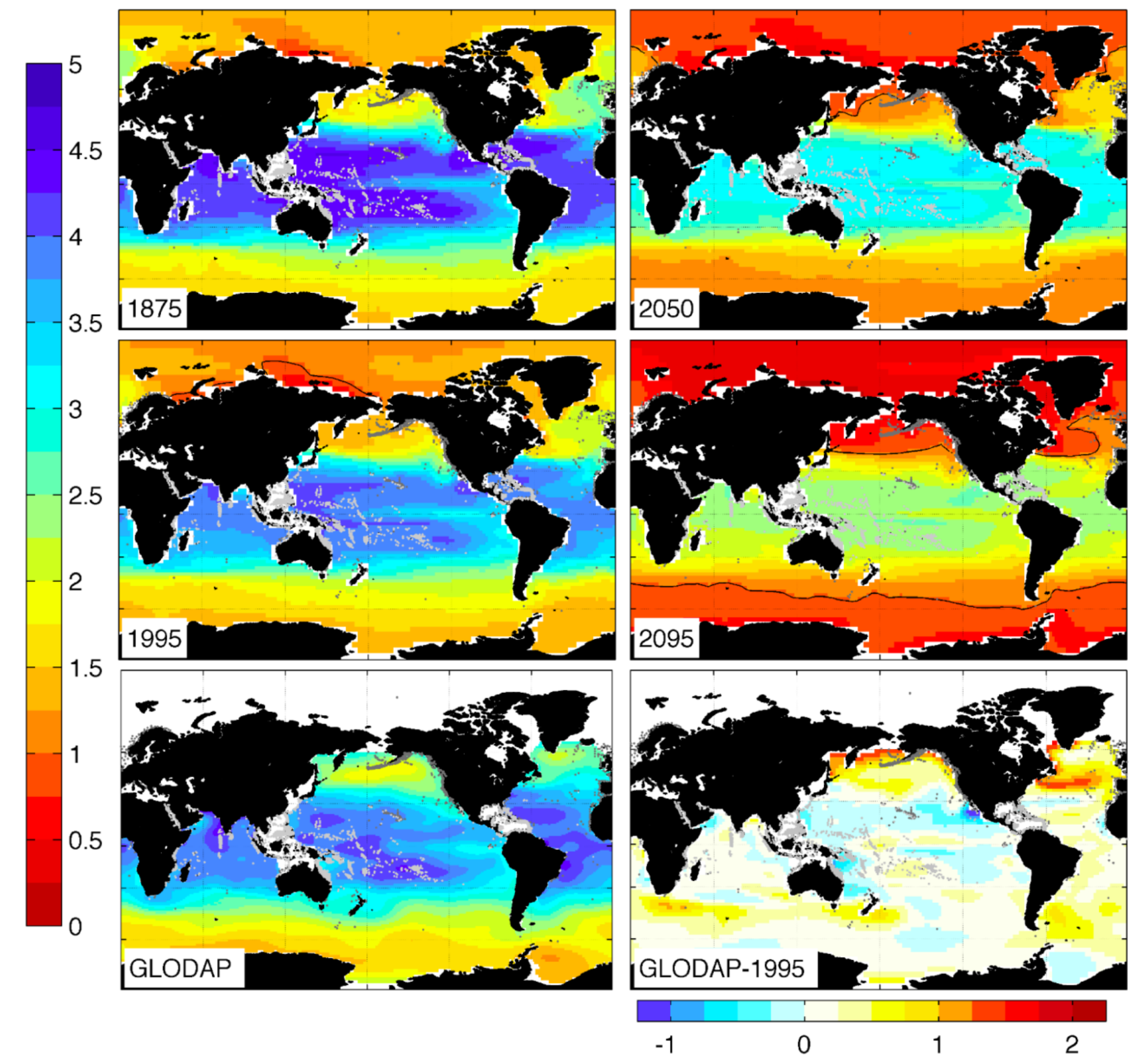
Rising CO_2 also reducing carbonate concentrations and pH

optimal

adequate

marginal

poor



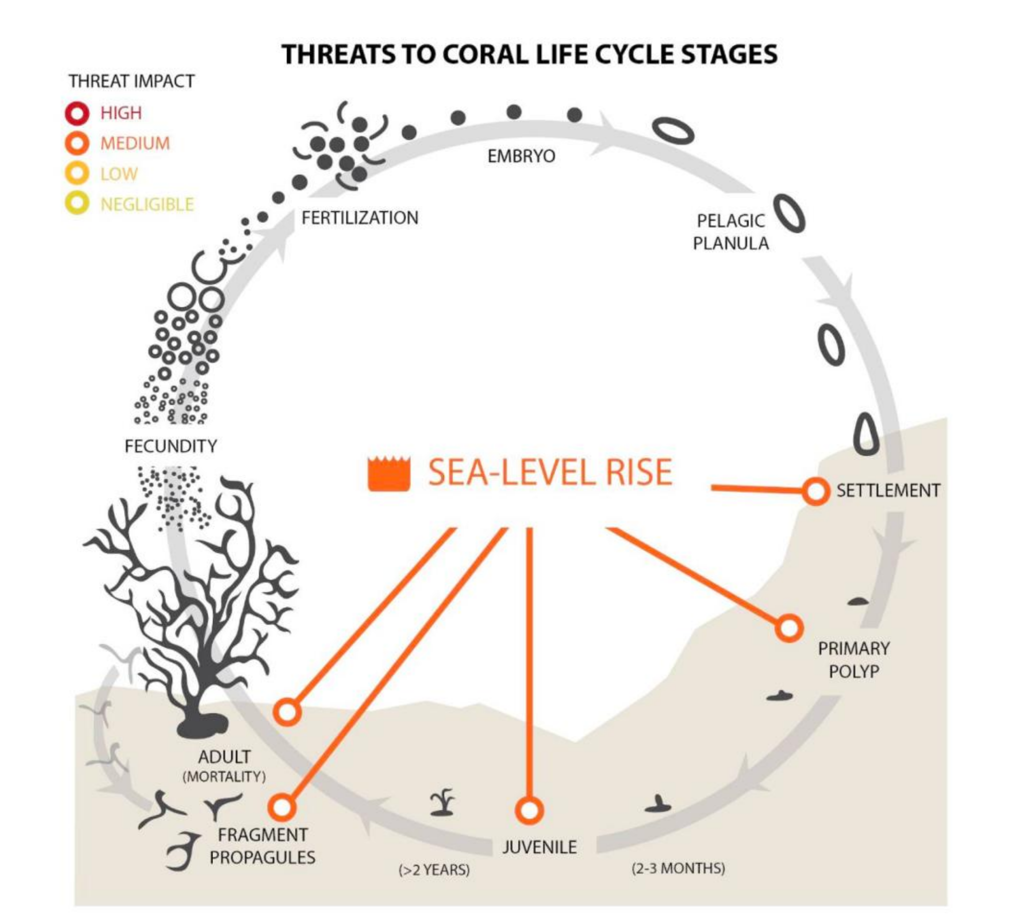
Impacts of Acidification

Genus (Pacific)	Response to elevated CO_2	Response Direction
Stylophora	Decreased calcification	↓
Acropora (5 species)	Decreased calcification, reduced larval success, increased bleaching	↓
Montipora (3 species)	Decreased calcification, net productivity increase	↓
Astrangia	Nutrient dependent decrease in calcification	↓
Porites (3 species)	Increased net production (in low nutrients), decreased calcification, increased bleaching	↓
Pavona	Lower calcification rate, altered crystal structure	↓
Galaxea	Lower calcification rate,	↓
Turbinaria	Lower calcification rate, altered crystal structure	↓

Other Impacts of Acidification

- Decreased cementation
- Increased bioerosion and chemical erosion
- Evidence acidification impairs reproductive success
- Even stronger impact on coralline algae with important role in coral settlement
- Reduces detection of reefs by coral larvae
- Reduced reef resilience

Other Climate Threats: Sea level rise of 1-2 m by 2100 most likely

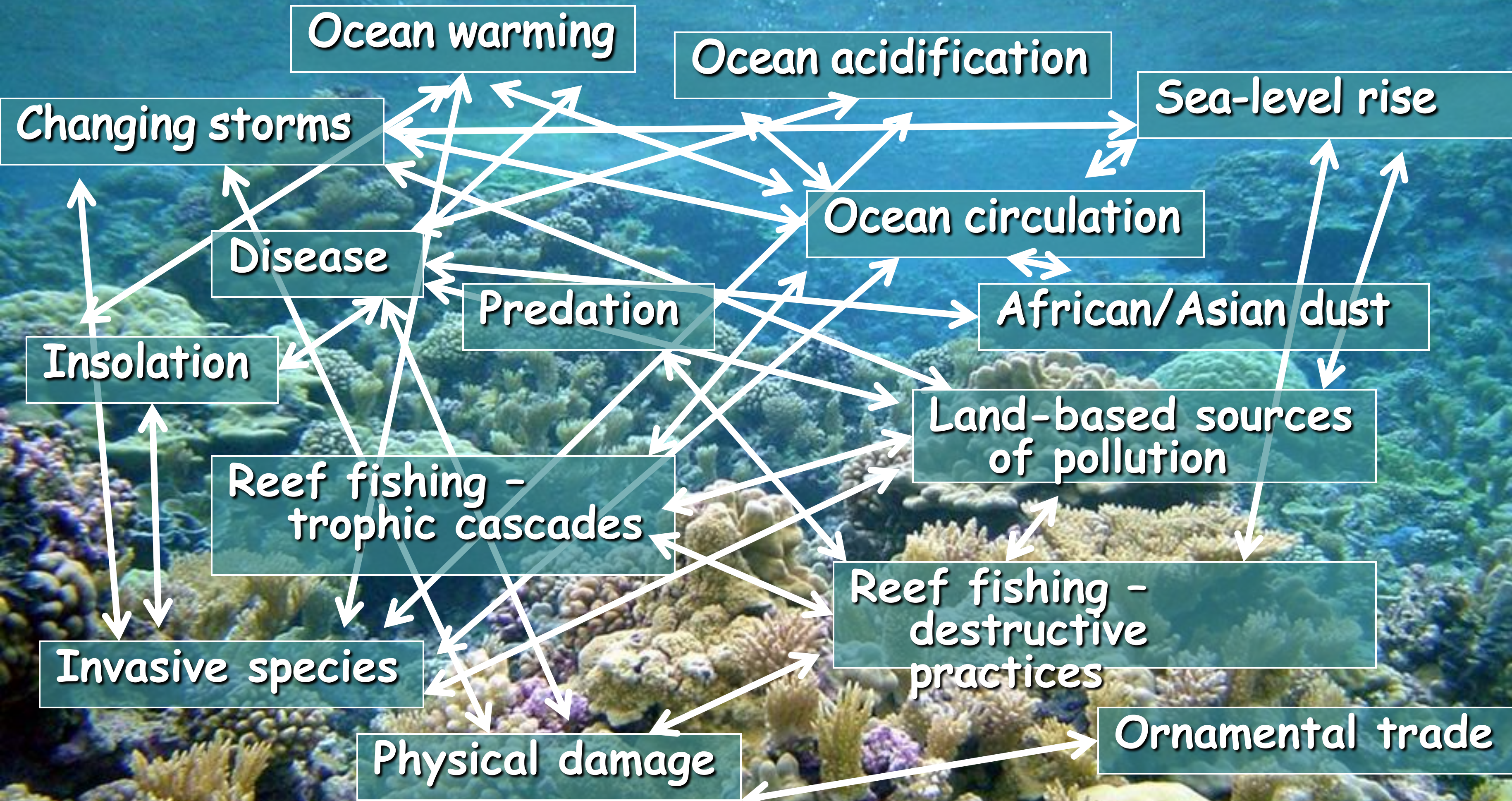


Threat Low-Medium

Geographic Variability of Climate Change Threats

	Indo-Pacific	Eastern Pacific	Western Atlantic
Coral Genera	91	10	25
Coral species	~ 700	40	65
Concentration of Thermal Stress	Varied	Very High	Medium-High in Gulf & Caribbean
Bleaching Impact	Generally lowest	Very high, probable extinction (*Millepora boschmai*)	High
Rate of Acidification	Generally lowest	Slow change, pH already low	Highest

Interactive & Unmeasureable (?)



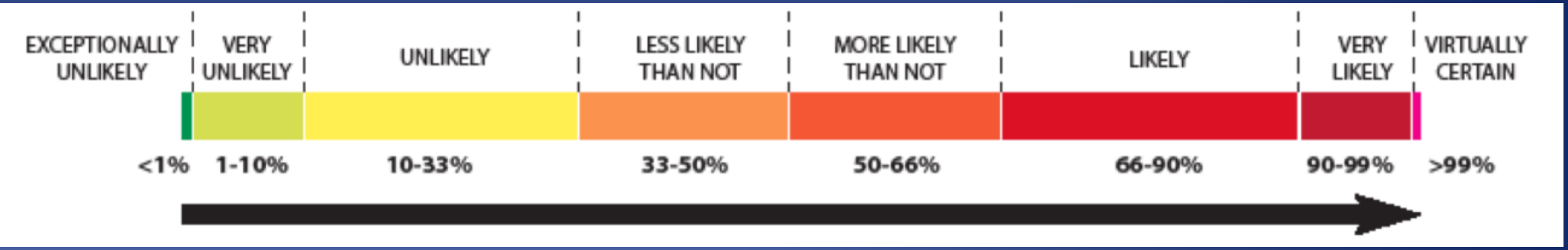
Concurrent, dynamic, interactive processes operating across diverse spatial/temporal scales

Extinction Risk Analysis

- Likelihood of a species population falling below a Critical Risk Threshold by the year 2100,
  - a time frame where climate projections are readily available and sufficiently scientifically-vetted (IPCC AR4).
- Critical Risk Threshold was defined by the BRT as a condition where a species is of such low abundance, so spatially fragmented, or at such reduced genetic and genotypic diversity that extinction is extremely likely
  - Critical Risk Threshold is based on consideration of:
    - depensatory processes (e.g., declining reproductive output due to low population density of sessile broadcast spawners),
    - environmental stochasticity (non-deterministic), and
    - catastrophic events.
- The general approach used was similar to the following:
  - Good, T. P., Waples R. S., Adams P., and (eds). 2001. Updated status of federally listed ESUs of West Coast salmon and steelhead. NMFS-NWFSC-66. NOAA Tech. Memo. NMFS-NWFSC-66 598 p. U.S. Dept. Commerce, 598 p.
  - IPCC. 2001. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (R. K. Pachauri, and A. Reisinger, eds.), 104 p. Intergovernmental Panel on Climate Change, Geneva, Switzerland.
  - Pew Center on Global Climate Change. 2007. Highlights from Climate Change 2007 Synthesis Report of the IPCC Fourth Assessment Report: Summary for Policy Makers.

BRT Risk Evaluation Process

- After presentation of existing knowledge and discussion about each of the 82 candidate coral species, each BRT member confidentially voted using 10 ‘likelihood’ points (similar to FKW BRT) in 8 Critical Risk Threshold categories (similar to IPCC).



- BRT discussed outcomes of 1st vote, then confidentially voted again.
- Each BRT member voted at least twice for each of the 82 candidate coral species. In some cases, particularly when new information was identified in discussion or thereafter, additional votes were made.
- BRT members typically spread their votes across multiple risk categories due to uncertainty based on lack of information.
- This large uncertainty is reflected for both individual species accounts and in means and modes for all species combined.

Individual Species Accounts

7.17.3 *Species Names* **: Veron, 1990**

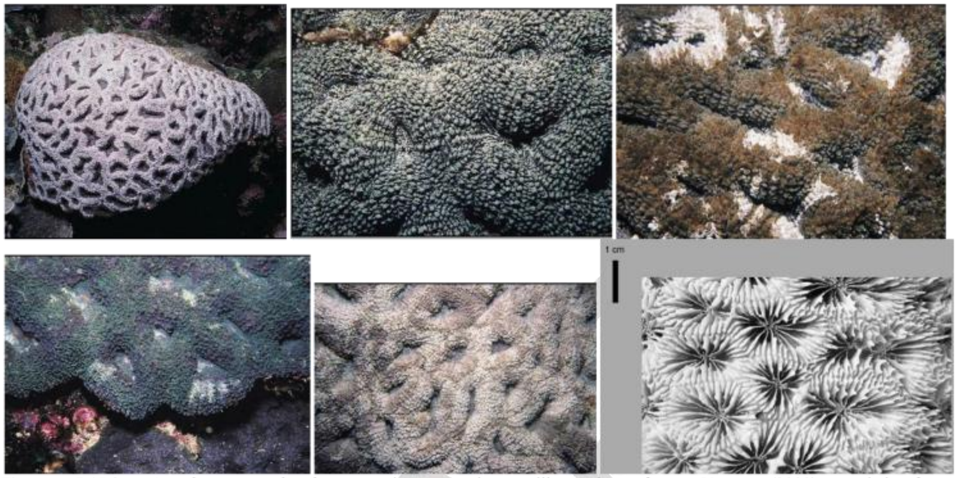


Figure 7.17.9. *Acanthastrea ishigakiensis* photos and corallite plan from Veron (2000) copied from http://data.aims.gov.au/coralpages/HTML/401-500/Species%20pages/442.htm.

Characteristics

Colonies are massive, usually hemispherical and often over 0.5 m across. Corallites are up to 25 mm diameter and cerioid, becoming plocoid on the colony sides. Septa are mostly uniform, with large teeth. Colonies have thick fleshy tissue over the skeleton. Colonies are uniform blue-grey or mixtures of grey, brown, cream and green in color, usually with mouth, oral disc and walls of contrasting colors. (Veron 2000).

Taxonomy

Taxonomic issues: None. *Acanthastrea ishigakiensis* is similar to *A. hillae*, which has smaller corallites with a tendency to form valleys. It resembles *Symphyllia erythraea* underwater (Veron 2000).

Family: Mussidae.

Evolutionary and geologic history: Genus known in the Indo-Pacific from the Miocene (Wells and Moore 1956).

Global Distribution

Acanthastrea ishigakiensis has a broad range; it stretches from the Red Sea, Gulf of Aden, and southern Africa to the central Pacific Ocean as far as Samoa but not including Australia.

Figure 7.17.10. *Acanthastrea ishigakiensis* distribution from IUCN copied from http://www.iucnredlist.org.

Figure 7.17.11. *Acanthastrea ishigakiensis* distribution from Veron (2000) copied from http://data.aims.gov.au/coralpages/HTML/401-500/Species%20pages/442.htm.

U.S. Distribution

According to the IUCN Species Account, *Acanthastrea ishigakiensis* occurs in American Samoa and the Northern Mariana Islands, but no supporting reference is given for the record of occurrence in either of these areas in the IUCN Species Account.

The CITES species database does not include any record of occurrence in U.S. waters. *A. ishigakiensis* is not listed as occurring in American Samoa in Lovell and McLardy (2008). In Veron (2000) (volume 3, page 17) the distribution map for this species includes the Mariana Archipelago, with a photo taken by Gustav Paulay labeled "Guam." However, Paulay (pers. comm. to J. Kenyon via email 2/28/2010) indicates a number of photos submitted by him to Veron from Palau, the Cook Islands, and other locations in the Pacific were mistakenly attributed to Guam (similar to the *errata* later acknowledged by Veron (2002) for *Acanthastrea regularis* and *Porites napopora*). There are no substantiated records of its occurrence in the Mariana Archipelago (J. Veron pers. comm. to J. Kenyon via email 4/23/2010).

Fenner reports a single colony of *A. ishigakiensis* in American Samoa at Tutuila (CRED unpubl. data-b). Visual identifications are supported by photographs (3), but no voucher sample was collected. The colony was photographed at Matuu, Tutuila. The species is relatively easy to identify, as it has large corallites, which are often pinched sideways, and it forms massive colonies unlike *A. hillae* which forms encrusting colonies.

This species was not observed elsewhere in American Samoa by Fenner during dedicated surveys conducted at 38 sites off Ofu-Olosega, Ta'u, Rose Atoll, Swains, and South Bank in March 2010. No other published or unpublished data sources indicate the occurrence of *A. ishigakiensis* elsewhere in U.S. waters.

Acanthastrea ishigakiensis has not been recorded from federally protected waters.

Habitat

Habitat: Shallow protected reef environments (Veron 2000).

Depth range: 1–15 m (Carpenter et al. 2008).

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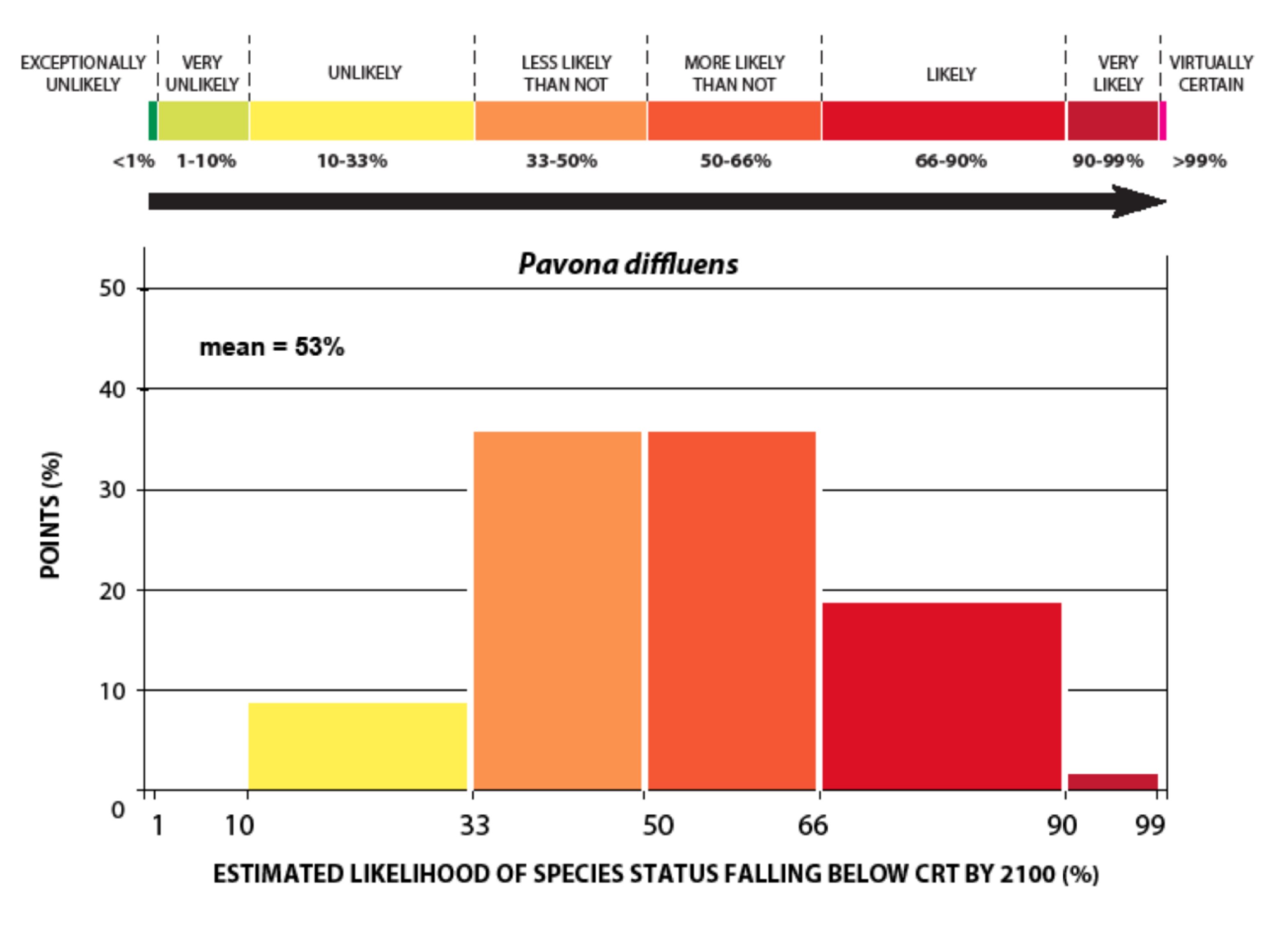
Example - Estimated Likelihood



Results for all 82 Species

Caribbean species in red

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELIHOOD (%)	SE OF BRT MEANS (%)	MEAN LIKELIHOOD RANGE (%)
	<1	1-10	10-33	33-50	50-66	66-90	90-99	>99			
Montastraea annularis	0	0	0	0	19	29	22	0	78	6.9	45.4
Montastraea faveolata	0	0	0	0	19	29	22	0	78	6.9	45.4
Acropora lokani	0	0	0	1	17	34	18	0	77	8.1	50.1
Acropora jacquelineae	0	0	0	1	17	37	15	0	76	7.3	50.1
Dendrogyra cylindrus	0	0	0	1	22	33	14	0	74	6.6	48.9
Montastraea franksi	0	0	0	3	25	24	18	0	74	9	47.9
Mycetophyllia ferox	0	0	0	5	26	30	9	0	70	8.2	50
Acropora rudis	0	0	0	9	19	34	8	0	70	11.2	49
Acropora dendrum	0	0	0	4	30	29	7	0	69	5.6	55
Pocillopora elegans (E Pacific)	0	0	3	7	25	26	9	0	67	13	53.4
Montipora patula (verrilli)	0	0	0	11	28	24	7	0	66	9.9	50.1
Acropora donei	0	0	0	13	28	26	3	0	64	8.2	52.6
Acropora pharaonis	0	0	0	15	27	23	5	0	64	8.9	55
Euphyllia paradivisa	0	0	0	15	28	22	5	0	63	9.6	50.3
Millepora foveolata	0	0	0	16	26	25	3	0	63	9.8	50.3
Millepora tuberosa	0	0	0	17	25	25	3	0	63	10.1	50.3
Euphyllia paraancora	0	0	0	17	27	21	5	0	63	10.4	50.3
Isopora cuneata	0	0	0	15	29	24	2	0	62	8.5	51.3
Euphyllia cristata	0	0	0	19	26	21	4	0	62	10.5	50.3
Montipora dilatata/flabellata (turgescens)	0	0	0	17	30	20	3	0	61	7.3	56.1
Agaricia lamarcki	0	0	0	17	29	23	1	0	61	6.3	54.9
Anacropora spinosa	0	0	0	22	27	19	2	0	59	7.5	54.9
Dichocoenia stokesi	0	0	0	19	33	17	1	0	59	5.1	58.3
Acropora microclados	0	0	3	19	27	19	2	0	58	11	60.3
Montipora lobulata	0	0	3	23	22	18	4	0	58	11.9	57.1
Acropora striata	0	0	2	21	27	19	1	0	58	8.4	58.1
Acropora listeri	0	0	3	18	31	17	1	0	58	6.7	64.9
Acropora globiceps	0	0	2	21	29	17	1	0	57	8.1	58.1
Pachyseris rugosa	0	0	3	23	24	18	2	0	57	10.8	57.1
Alveopora fenestrata	0	0	0	28	23	18	1	0	57	8.5	52.6
Alveopora allingi	0	0	0	27	25	17	1	0	57	8.7	52.6
Montipora australiensis	0	0	3	25	22	17	3	0	57	12	53.7
Anacropora puertogalerae	0	0	2	24	26	16	2	0	57	8.1	60.1
Acropora tenella	0	0	2	22	28	18	0	0	57	7.7	58.1
Montipora angulata	0	0	3	26	21	17	3	0	57	11.9	53.7
Isopora crateriformis	0	1	4	20	24	20	1	0	57	14.2	51.3
Montipora caliculata	0	0	3	25	23	16	3	0	57	11.6	53.7
Alveopora verrilliana	0	0	0	29	24	16	1	0	56	9	49.1
Montipora calcarea	0	0	3	26	23	15	3	0	56	11.6	53.7
Caulastrea echinulata	0	0	5	21	28	13	3	0	56	9.6	62.6
Seriatopora aculeata	0	0	4	25	25	15	1	0	55	10.3	59.1

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELIHOOD (%)	SE OF BRT MEANS (%)	MEAN LIKELIHOOD RANGE (%)
	<1	1-10	10-33	33-50	50-66	66-90	90-99	>99			
Acropora speciosa	0	0	4	25	25	16	0	0	55	10.1	54.4
Acropora verweyi	0	0	7	21	25	16	1	0	54	11.5	59.1
Acropora retusa	0	0	6	25	22	15	2	0	54	13.2	55.7
Pocillopora danae	0	0	8	20	28	11	3	0	54	13.7	52.3
Pavona diffluens	0	0	6	25	25	13	1	0	53	12	61.4
Acropora paniculata	0	0	5	26	26	12	1	0	53	9.4	49.9
Acropora polystoma	0	0	6	26	25	12	1	0	53	9.9	61.3
Acropora vaughani	0	0	8	24	24	13	1	0	52	11.2	61.3
Astreopora cucullata	0	0	8	25	24	11	2	0	52	9.2	59
Barabattoia laddi	0	0	4	28	29	8	1	0	52	12.6	51.1
Acropora palmerae	0	0	7	24	28	11	0	0	52	8.8	60
Acropora horrida	0	0	5	27	29	9	0	0	52	6.8	56.7
Physogyra lichtensteini	0	0	10	25	22	12	1	0	51	11.4	62.3
Porites horizontalata	0	0	10	25	22	12	1	0	51	11.7	62.3
Pocillopora elegans (W Pacific)	0	2	9	23	23	12	1	0	50	14.6	56.9
Porites napopora	0	0	8	27	27	8	0	0	50	9.1	57.7
Acanthastrea brevis	0	0	8	28	26	7	1	0	50	9.1	57.7
Acanthastrea hemprichii	0	0	8	28	26	7	1	0	50	9.1	57.7
Acanthastrea ishigakiensis	0	0	8	28	26	7	1	0	50	7	59.9
Porites nigrescens	0	0	8	29	25	7	1	0	50	8.9	57.7
Acropora acuminata	0	0	9	25	30	6	0	0	49	8.5	56.6
Acropora aculeus	0	0	11	22	30	7	0	0	49	11.8	51
Pectinia alcicornis	0	0	16	22	20	10	2	0	48	15.6	58.9
Acropora aspera	0	1	9	24	31	5	0	0	48	9.3	57.9
Pavona bipartita	0	0	10	28	26	6	0	0	48	10.9	47.4
Acanthastrea regularis	0	3	8	26	25	8	0	0	48	15	46.6
Pavona cactus	0	0	12	27	24	7	0	0	47	10.7	47.4
Pavona decussata	0	0	11	28	25	6	0	0	47	10.7	50.7
Pavona venosa	0	0	11	28	25	6	0	0	47	12	48.3
Cyphastrea agassizi	0	0	15	22	25	8	0	0	47	13.8	51.7
Cyphastrea ocellina	0	0	15	23	24	8	0	0	47	13.7	51.7
Turbinaria stellulata	0	0	8	33	29	0	0	0	46	5.9	40.6
Galaxea astreata	0	1	9	34	24	2	0	0	45	7.5	51.9
Psammacora stellata	0	2	18	30	18	2	0	0	41	9.2	58.4
Leptoseris incrustans	0	6	17	27	17	3	0	0	39	10.3	61.1
Leptoseris yabei	0	6	18	25	19	2	0	0	39	11.1	57.7
Turbinaria mesenterina	0	3	19	36	12	0	0	0	37	9.5	45.1
Turbinaria peltata	0	3	19	36	12	0	0	0	37	[illegible]	45.1
Turbinaria reniformis	0	3	19	36	12	0	0	0	37	[illegible]	45.1
Heliopora coerulea	0	4	24	28	11	3	0	0	37	[illegible]	54.1
Porites (Clade 1 forma pukoensis)*	0	30	25	14	1	0	0	0	19	8.3	43.1
all votes summed	0	65	494	1750	1981	1209	241	0			
frequency of species per likelihood bin	0	13	57	80	82	77	57	0			
percentage of species per likelihood bin (%)	0	16	70	98	100	94	70	0			
mean likelihood score frequency	0	0	1	25	46	10	0	0			

Results

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELIHOOD (%)	SE OF BRT MEANS (%)	MEAN LIKELIHOOD RANGE (%)
	<1	1-10	10-33	33-50	50-66	66-90	90-99	>99			
Montastraea annularis	0	0	0	0	19	29	22	0	78	6.9	45.4
Montastraea faveolata	0	0	0	0	19	29	22	0	78	6.9	45.4
Acropora lokani	0	0	0	1	17	34	18	0	77	8.1	50.1
Acropora jacquelineae	0	0	0	1	17	37	15	0	76	7.3	50.1
Dendrogyra cylindrus	0	0	0	1	22	33	14	0	74	6.6	48.9
Montastraea franksi	0	0	0	3	25	24	18	0	74	9	47.9
Mycetophyllia ferox	0	0	0	5	26	30	9	0	70	8.2	50
Acropora rudis	0	0	0	9	19	34	8	0	70	11.2	49
Acropora dendrum	0	0	0	4	30	29	7	0	69	5.6	55
Pocillopora elegans (E Pacific)	0	0	3	7	25	26	9	0	67	13	53.4
Montipora patula (verrilli)	0	0	0	11	28	24	7	0	66	9.9	50.1
Acropora donei	0	0	0	13	28	26	3	0	64	8.2	52.6
Acropora pharaonis	0	0	0	15	27	23	5	0	64	8.9	55
Euphyllia paradivisa	0	0	0	15	28	22	5	0	63	9.6	50.3
Millepora foveolata	0	0	0	16	26	25	3	0	63	9.8	50.3
Millepora tuberosa	0	0	0	17	25	25	3	0	63	10.1	50.3
Euphyllia paraancora	0	0	0	17	27	21	5	0	63	10.4	50.3
Isopora cuneata	0	0	0	15	29	24	2	0	62	8.5	51.3
Euphyllia cristata	0	0	0	19	26	21	4	0	62	10.5	50.3
Montipora dilatata/flabellata (turgescens)	0	0	0	17	30	20	3	0	61	7.3	56.1
Agaricia lamarcki	0	0	0	17	29	23	1	0	61	6.3	54.9
Anacropora spinosa	0	0	0	22	27	19	2	0	59	7.5	54.9
Dichocoenia stokesi	0	0	0	19	33	17	1	0	59	5.1	58.3
Acropora microclados	0	0	3	19	27	19	2	0	58	11	60.3
Montipora lobulata	0	0	3	23	22	18	4	0	58	11.9	57.1
Acropora striata	0	0	2	21	27	19	1	0	58	8.4	58.1
Acropora listeri	0	0	3	18	31	17	1	0	58	6.7	64.9
Acropora globiceps	0	0	2	21	29	17	1	0	57	8.1	58.1
Pachyseris rugosa	0	0	3	23	24	18	2	0	57	10.8	57.1
Alveopora fenestrata	0	0	0	28	23	18	1	0	57	8.5	52.6
Alveopora allingi	0	0	0	27	25	17	1	0	57	8.7	52.6
Montipora australiensis	0	0	3	25	22	17	3	0	57	12	53.7
Anacropora puertogalerae	0	0	2	24	26	16	2	0	57	8.1	60.1
Acropora tenella	0	0	2	22	28	18	0	0	57	7.7	58.1
Montipora angulata	0	0	3	26	21	17	3	0	57	11.9	53.7
Isopora crateriformis	0	1	4	20	24	20	1	0	57	14.2	51.3
Montipora caliculata	0	0	3	25	23	16	3	0	57	11.6	53.7
Alveopora verrilliana	0	0	0	29	24	16	1	0	56	9	49.1
Montipora calcarea	0	0	3	26	23	15	3	0	56	11.6	53.7
Caulastrea echinulata	0	0	5	21	28	13	3	0	56	9.6	62.6
Seriatopora aculeata	0	0	4	25	25	15	1	0	55	10.3	59.1

<u>High Risk</u>
5 of top 7 highest risk species from Caribbean (shown in red font).

Overall mean across all 82 candidate coral species was 55%

>> More likely than not to fall below Critical Risk Threshold by 2100

Results - Graphic

<u>High Uncertainty</u>

Mean spread (range) of votes for each BRT Member was 53.75%

Mean Standard Error between BRT means for the 82 species was 9.9%

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Limitations of BRT Approach

- Expert-based approaches are subjective.
- Links between available information and conclusions are not readily transparent.
- “Rules” used by BRT members were not explicit, and hence not repeatable.
- The Federal Advisory Committee Act necessitated BRT consist of Federal experts—the pool of qualified and available individuals was limited.
- The short, ambitious deadline was challenging for evaluation of 82 candidate species with global range and limited data.

Strengths of BRT Approach

- All available relevant information was considered.
- Approach was relatively expeditious (i.e., tight ESA timeline).
- Approach explicitly considered uncertainty about all information.
- Approach could be applied in cases with limited information.
- Approach did not require consensus (but it was generally reached).
- The result represented an aggregate result of experts with varying perceptions of risk to the species.

Summary

- Comprehensive synopses and extinction risk assessment of 82 species of corals
- Evaluation of a broad range of potential threats, the most important extinction risks were posed by the following global threats:
  - ocean warming,
  - coral disease,
  - ocean acidification, all directly or indirectly related to greenhouse gas emissions
- The mean estimated likelihood of falling below the Critical Risk Threshold by 2100 ranged from 78% ('likely') to 19% ('unlikely') among the 82 candidate coral species.
- The overall mean and the median estimated Critical Risk Threshold across all 82 candidate coral species both exceeded 50% likelihood, thereby falling into the 'more likely than not' category.
- The BRT concluded, with high uncertainty, that most of the 82 candidate coral species are 'more likely than not' to fall below the Critical Risk Threshold by 2100.

Summary (con't)

- Caribbean species were estimated to have relatively high probabilities of falling below the Critical Risk Thresholds by 2100 with 5 of the top 7 candidate species from that region.
  - reflects the small geographic extent,
  - pervasive and demonstrated impacts of both local and global threats,
  - significant and well-documented declines of corals in the Caribbean region.
- Other high-risk species have highly restricted geographic ranges, demonstrated low population sizes, and/or extreme vulnerabilities to one or more threats.
- Lower risk species tended to have wide geographic and habitat distributions, tolerance to marginal environmental conditions, and/or known tolerance of important threats.
- The BRT identified increasing human population and the intensity of their collective consumption as the root drivers of almost all global and local threats to coral species.

Peer-Review Process

Draft report sent to Center for Independent Experts

- Terry P. Hughes, Director, ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD Australia
- John W. McManus, Director, National Center for Caribbean Coral Reef Research and Professor, Division of Marine Biology and Fisheries, Rosenstiel School of Marine & Atmospheric Science, University of Miami, Miami, Florida.
- Bernhard Riegl, Professor and Associate Director of the National Coral Reef Institute, NOVA Southeastern University, Fort Lauderdale-Davie, Florida.

Peer-Review Process

- BRT responded to CIE review comments in a separate internal report and revised draft where appropriate
- Draft report submitted to PIFSC internal publications process
  - Internal review by PhD stock assessment biologist and Center director
  - Final draft revised accordingly
- Status review published as NOAA Technical memorandum (held pending listing decision)
  - Report submitted to NMFS Pacific Islands Regional Administrator

Questions?

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